

Extranuclear Inheritance

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The past couple of lectures, we've been exploring exceptions to Mendel's principles of transmission inheritance.

Scientists have observed inheritance patterns that do not fit either Mendelian principles or the extensions of Mendelian genetics.

Now that DNA has been discovered in places outside the nucleus, these phenomena are explained.

Types of Extranuclear Inheritance

1. Maternal (organelle) inheritance
2. Infectious inheritance
3. Maternal effect on phenotype

Maternal (Organelle) Inheritance

DNA contained in mitochondria or chloroplasts determines the phenotype of the offspring.

These phenotypes arise due to the source of organelles—only from the egg—such that there is only a maternal influence on phenotype.

Infectious Inheritance

The symbiotic or parasitic association of microorganism with a host organism results in transmission of a phenotype in offspring of the host offspring.

Maternal Effect on Phenotype

mRNA transcripts stored in the egg prior to fertilization influence phenotype of the individual after fertilization by a sperm.

These mRNA transcripts are used to initiate metabolism of the newly formed individual, a kind of “jump start” before the new genome is used.

Maternal (Organelle) Inheritance

Mitochondria are the “power plants” of the eukaryotic cell.

Mitochondria are characterized by an inner and outer membrane. Components of the electron transport chain are incorporated into the inner membrane.

The mitochondria are the source of the citric acid (TCA or Krebs) cycle, used to produce ATP from energy sources.

Mitochondria

Mitochondria Inner Structure

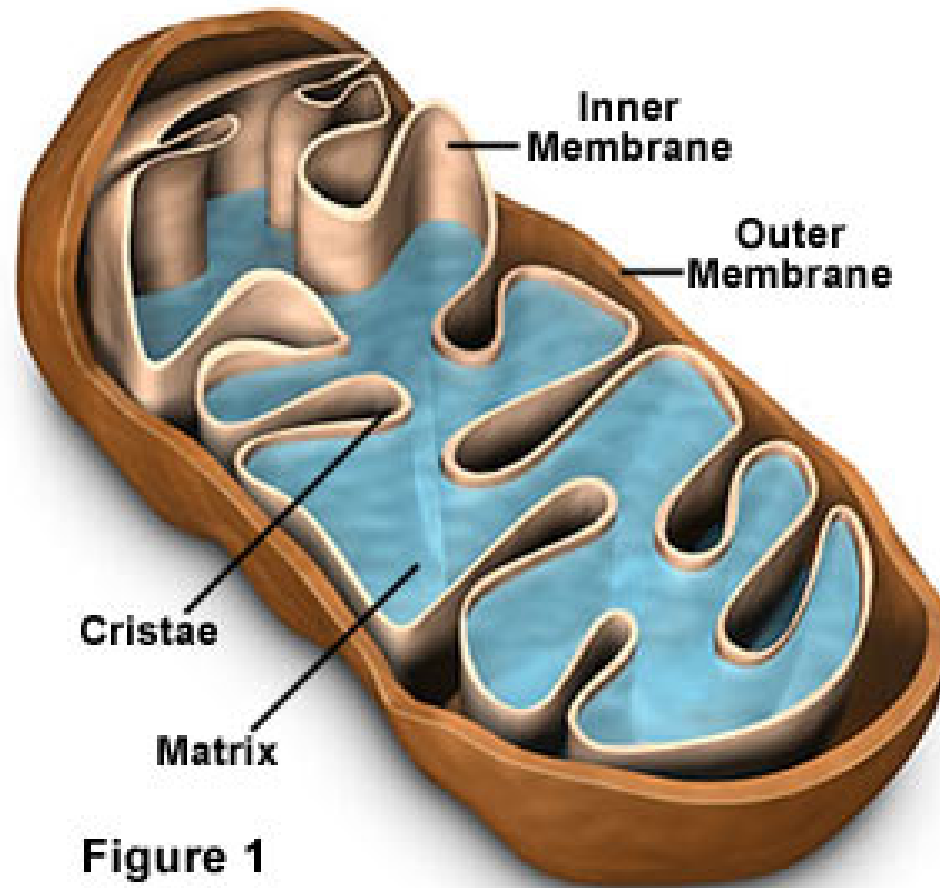
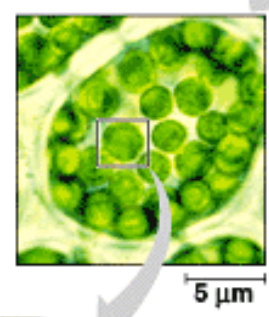
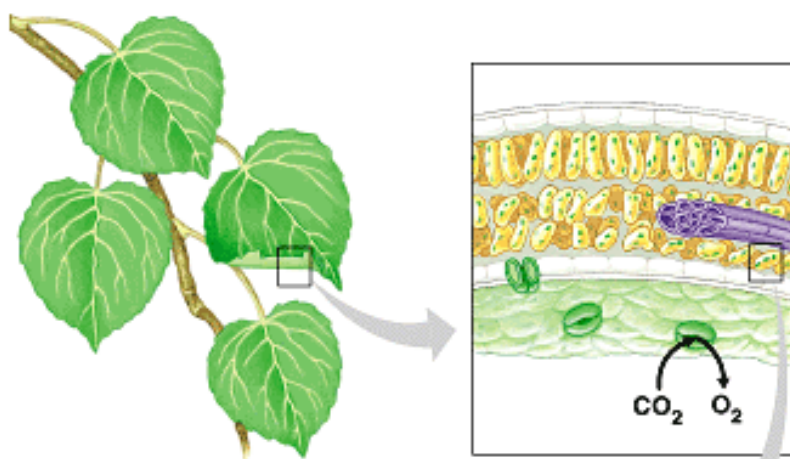


Figure 1

Maternal (Organelle) Inheritance

Chloroplasts are the organelles responsible for photosynthesis in plants.

Like mitochondria, chloroplasts are membrane-bound organelles that contain their own DNA.



Maternal (Organelle) Inheritance

Both mitochondria and chloroplasts contain DNA.

1. mtDNA and cpDNA are inherited independently of nuclear DNA
2. Function of mitochondria and chloroplasts is dependent on both organelle and nuclear DNA
3. Each cell contains as many as several hundred chloroplasts and/or mitochondria.

Leaf Color in Four O'Clocks

Inheritance is determined by the phenotype of the ovule (egg).

Leaf Color in Four O'Clocks

<u>Pollen Source</u>		<u>Ovule Source</u>	
	White	Green	Variegated
White	White	Green	W, G, var
Green	White	Green	W, G, var
Variegated	White	Green	W, G, var

Leaf Color



Leaf Color



Organelle Inheritance

Mutations in chloroplasts and mitochondria have been useful in identifying organelle inheritance patterns.

Inheritance of these mutations was determined by the makeup of the organelle DNA.

It is important to note that an individual cell has hundreds of chloroplasts and/or mitochondria, which may not all be identical.

Mitochondrial Depletion Syndrome

Mitochondrial Depletion Syndrome is a maternally inherited disease characterized by multiple muscular and neural symptoms, with a wide variety of severity in different individuals.

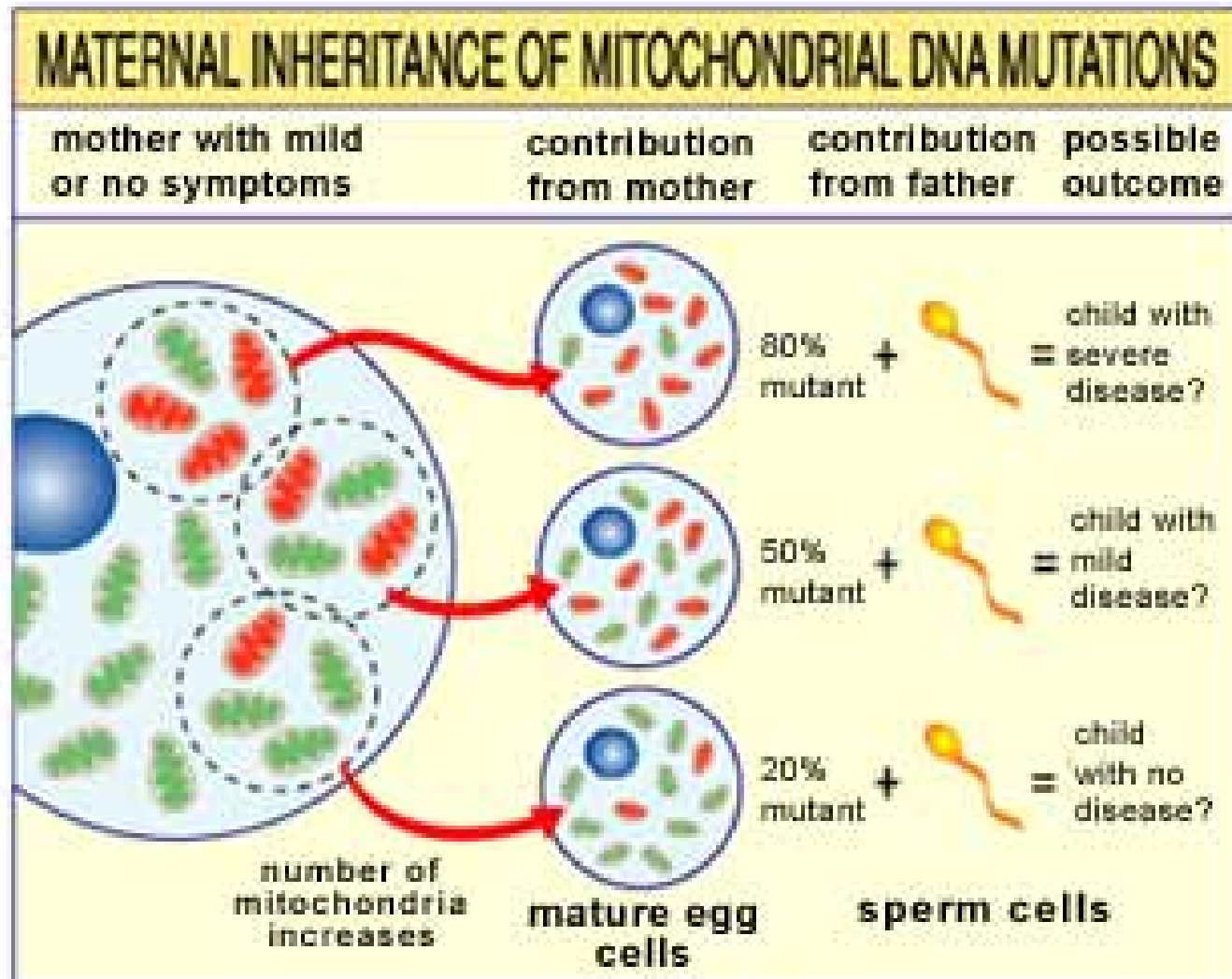
Mitochondrial Syndromes

The severity of the condition is dependent on the number of disabled mitochondria present in the egg.

An egg with a large number of disabled mitochondria would result in a child with severe abnormalities

An egg with only a few disabled mitochondria would result in an individual only mildly affected.

Mitochondrial Inheritance



Organelle Genomes

Both mitochondria and chloroplasts replicate their own DNA in the process of replicating the organelles.

These organelles also possess the ability to express genes from their genomes.

The DNA organization is very similar to that of bacteria and viruses.

Endosymbiotic Hypothesis

It is thought that chloroplasts and mitochondria arose from ancient bacteria engulfed by primitive eukaryotic cells.

The cells developed a symbiotic relationship that gave the eukaryotic cells the ability to respire aerobically (mitochondria) and capture light energy (chloroplasts).

Infectious Heredity

An invading microorganism may exist in a symbiotic relationship with its host organism. The invader is then passed on in the maternal egg cytoplasm (ooplasm) and confers the beneficial phenotype to the offspring.

Infectious Heredity in *Drosophila*

CO₂ sensitivity: Affected flies do not recover normally from CO₂ anesthesia. They become permanently paralyzed and die.

The condition is due to a sensitivity to a virus, **sigma**.

Infectious Heredity in *Drosophila*

Sex ratio: Affected flies produce predominantly female offspring if reared at 21°C or lower. The condition is transmitted only to daughters, not to the small number of males produced.

The responsible element is a protozoan. When ooplasm from affected individuals or the protozoan itself is injected into oocytes of normal individuals, the temperature-sensitive, altered sex ratio condition results.

Maternal Effect

The maternal genome has a strong effect on early developmental events in the newly formed individual after fertilization.

Numerous transcripts are synthesized off the maternal genome during oogenesis. These RNA transcripts are not immediately translated; instead, they are preserved in the oocyte.

Maternal Effect

When the oocyte has been fertilized, these transcripts are translated to provide the proteins necessary to drive metabolism and the initial developmental events in the zygote.

These transcripts serve to support the new individual until its own, unique genome is activated and can drive cell function.

Maternal Effect

Proteins are also archived in the oocyte. Like the archived mRNA molecules, these proteins are available to the zygote and used to drive cell metabolism.

Maternal Effect

The phenotype produced by these archived products is expressed in the zygote (genetically distinct from the mother) but is due entirely to the genotype of the mother.

Coiling in *Limnaea* snails



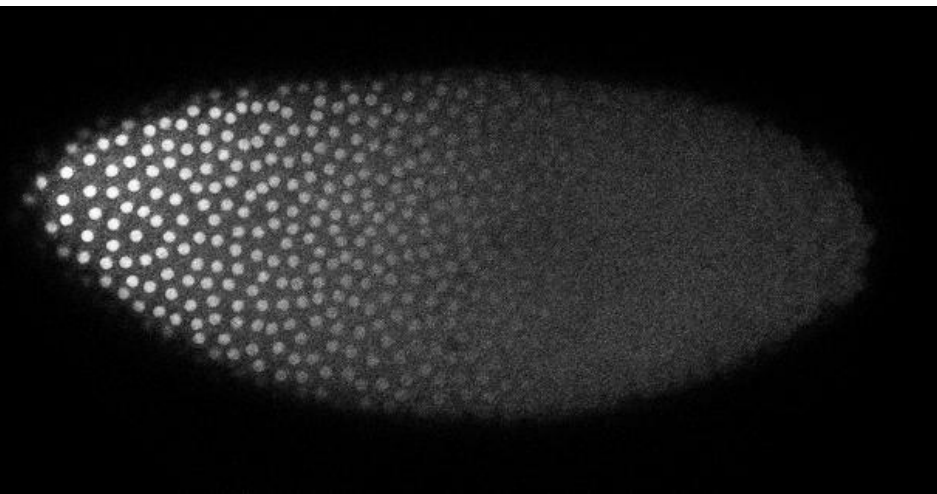
Whether the shell coils to the right (shown) or left is determined by the maternal genotype and is preserved in the oocyte. Dextral, or right-handed coiling is dominant to sinistral, or left-handed coiling.

Pattern Formation in *Drosophila*

The gene *bicoid* (*bcd*) is a gene that is involved in creating the anterior portion of the developing embryo. Embryos that are homozygous for a mutation in this gene fail to develop the embryonic portions that give rise to the head and thorax.

Embryos whose mothers contain at least one wild-type allele develop normally, even if the genotype of the embryo is homozygous for the mutation.

Anterior Formation



Bicoid protein accumulates in what will be the anterior portion of the embryo.

If the protein is not produced, the head/thorax structures will not form.